CLASS 10TH WORKSHEET CHAPTER - CALORIMETRY

Exercise 11(A) — Multiple Choice Type

Question 1

The total internal energy of all molecules of a substance is called :

1. magnetic energy
2. heat energy
3. thermal energy
4. electrical energy

Answer

thermal energy

Reason — Thermal energy refers to the total internal energy of a substance arising from the random motion and interactions of its constituent molecules. This internal energy includes the kinetic energy of the molecules (their motion) as well as the potential energy associated with their intermolecular forces and interactions.

Question 2

The unit of heat is :

1. Watt
2. Joule
3. Calorie
4. Both (2) and (3)

Answer

Both (2) and (3)

Reason — S.I. unit of heat is Joule (J). The other most commonly used unit of heat is Calorie (cal).

Question 3

The specific heat capacity of water is:

1. 4200 J kg^{-1} K^{-1}
2. 420 J g^{-1} K^{-1}
3. 0.42 J g^{-1} K^{-1}
4. 4.2 J kg^{-1} K^{-1}

Answer

4200 J kg^{-1} K^{-1}

Reason — Water has an unusually high specific heat capacity of 4200 J kg^{-1} K^{-1}

Question 4

Temperature determines the direction of :

1. flow of heat
2. flow of energy
3. flow of motion
4. none of the above

Answer

flow of heat

Reason — Temperature determines the direction of heat flow because heat naturally flows from regions of higher temperature to regions of lower temperature.

Question 5

The amount of heat energy contained in a body depends on its :

1. mass
2. temperature
3. material of the body
4. all of the above

Answer

all of the above

Reason — The amount of heat energy contained in a body depends on its

1. **Mass** — The greater the mass of a body, the more heat energy it can contain, assuming all other factors remain constant.
2. **Temperature** — The temperature of a body directly influences the amount of heat energy it contains. Higher temperatures indicate higher amounts of thermal energy.
3. **Material of the Body** — Different materials have different specific heat capacities, which determine how much heat energy is required to raise the temperature of the material by a certain amount.

Question 6

The correct relation between heat capacity and specific heat capacity is :

1. C'= m x c
2. C'= 1/mc
3. C'= m/c
4. C = mc'

Answer

C' = m x c

Reason — C'= m x c hence, the heat capacity (C') is directly proportional to both the mass (m) and the specific heat capacity (c).

Question 7

A good conductor of heat has a .... specific heat capacity, while a bad conductor has a .... specific heat capacity.

1. low, high
2. low, low
3. high, low
4. high, high

Answer

low, high

Reason — The substance with low specific heat capacity shows a rapid and high rise in temperature thus it is a better conductor of heat than the substance with high specific heat capacity which shows a slow and small rise in temperature.

Question 8

The specific heat capacity is maximum for :

1. copper
2. zinc
3. iron
4. hydrogen

Answer

hydrogen

Reason — The specific heat capacities of the given elements are:

Element	Specific Heat Capacity ($Jkg^{-1}K^{-1}$)
Copper	399
Zinc	391
Iron	483
Hydrogen	14630

Hence, Hydrogen has the highest specific heat capacity.

Question 9

The principle of calorimetry is based on :

1. law of conservation of heat
2. law of conservation of energy
3. both (1) and (2)
4. conservation of momentum

Answer

both (1) and (2)

Reason — Law of conservation of energy states that energy cannot be created or destroyed, only transferred or transformed from one form to another. In calorimetry, heat energy is exchanged between a system and its surroundings, but the total amount of heat energy in the system and surroundings remains constant, in accordance with these conservation laws.

Question 10

Heat is measured by:

1. thermometer
2. barometer
3. principle of calorimetry
4. both (1) and (2)

Answer

principle of calorimetry

Reason — Heat is measured by calorimetry, which involves the determination of heat changes in a system through the measurement of temperature changes.

Heat energy lost by a hot body = Heat energy gained by the cold body.

This is called the principle of calorimetry.

Question 11

Assertion (A): The specific heat capacity of a substance is the amount of heat required to raise the temperature of unit mass of that substance by 1°C.

Reason (R): The specific heat capacity of a substance is not its characteristic property.

1. Both A and R are true and R is the correct explanation of A
2. Both A and R are true and R is not the correct explanation of A
3. assertion is false but reason is true
4. assertion is true but reason is false.

Answer

assertion is true but reason is false.

Explanation

Assertion (A) is true. The specific heat capacity of a substance is the amount of heat required to raise the temperature of unit mass of the substance by 1°C (or 1 K).

Reason (R) is false. The specific heat capacity of a substance is its characteristic property. It represents the substance's ability to store heat energy per unit mass and is an intrinsic property that is unique to each substance.

Question 12

Assertion (A): The principle of the method of mixtures involves mixing substances at different temperatures to find the final temperature.

Reason (R): The law of conservation of energy states that the energy is neither created nor destroyed in an isolated system.

1. Both A and R are true and R is the correct explanation of A
2. Both A and R are true and R is not the correct explanation of A
3. assertion is false but reason is true

4. assertion is true but reason is false.

Answer

Both A and R are true and R is the correct explanation of A.

Explanation

Assertion (A) is true. The principle of the method of mixtures involves mixing substances at different temperatures to find the final temperature. This method is based on the principle that heat lost by the hotter substance is equal to the heat gained by the colder substance when they reach thermal equilibrium.

Reason (R) is true. The law of conservation of energy states that energy is neither created nor destroyed in an isolated system. This principle is fundamental in understanding heat transfer processes, including the method of mixtures. In the method of mixtures, the total energy of the system (the substances being mixed) remains constant, as energy is transferred from the hotter substance to the colder substance until thermal equilibrium is reached.

Exercise 11(A) — Very Short Questions

Question 1

Name the S.I. unit of heat.

Answer

The S.I. unit of heat is joule (J).

Question 2

How is the heat capacity of a body related to the specific heat capacity of it's substance?

Answer

The equation which relates the heat capacity of a body to the specific heat capacity is —

$$C = m \times c$$

Question 3

Name a liquid which has the highest specific heat capacity.

Answer

A liquid which has the highest specific heat capacity is **water**.

Question 4

Write the approximate value of specific heat capacity of water in S.I. unit.

Answer

The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

Question 5

Write the expression for the heat energy Q received by m kg of a substance of specific heat capacity c J kg^{-1} K^{-1} when it is heated through $\triangle t°$ C.

Answer

The expression for the heat energy Q is given by:

$Q = m \times c \times \triangle t$ joules,

where, c is specific heat capacity

m is mass of substance

$\triangle t$ is change in temperature

Question 6

Same amount of heat is supplied to two liquids A and B. The liquid A shows a greater rise in temperature. What can you say about the heat capacity of A as compared to that of B?

Answer

As the substance having low specific heat capacity will show a rapid and high rise in temperature and since liquid A shows a greater rise in temperature as compared to B when same amount of heat is supplied to both. Hence, **heat capacity of liquid A is less than that of B**.

Question 7

Give one example each where high specific heat capacity of water is used (i) as coolant, (ii) as heat reservoir.

Answer

(i) **Used as a coolant** — Radiators in car and generator use water for cooling. Water in car radiator can absorb more heat without much rise in temperature due to it's high specific heat capacity. Hence, in acts as an effective coolant.
(ii) **Used as heat reservoir** — In cold countries, water is used as heat reservoir for wine and juice bottles to avoid their freezing. The reason is that water due to it's high specific heat capacity can impart a large amount of heat before reaching to it's freezing point. Hence, bottles kept in water remain warm and do not freeze when there is considerable fall in temperature.

Question 8

A liquid X has specific heat capacity higher than the liquid Y. Which liquid is useful as (i) coolant in car radiators and, (ii) heat reservoir to keep juice bottles without freezing?

Answer

(i) **Coolant in car radiators** — Liquid X is used as a coolant in car radiators because liquid X has specific heat capacity higher than the liquid Y, hence it will absorb more heat energy without much change in temperature.
(ii) **Heat reservoir to keep juice bottles without freezing** — The liquid needs to give out large amount of heat before reaching freezing temperatures and as liquid X has specific heat capacity higher than the liquid Y, hence liquid X will be used.

Exercise 11(A) — Short Questions

Question 1

Define the term heat.

Answer

Heat is the internal energy of molecules constituting the body. It flows from a hot body to a cold body when they are kept in contact.

Question 2

Define the term calorie. How is it related to joule?

Answer

One calorie is the quantity of heat energy required to raise the temperature of 1 g of water from 14.5°C to 15.5°C.
1 calorie (or 1 cal) = 4.186 J or 4.2 J (nearly)

Question 3

Define one kilo-calorie of heat.

Answer

One kilo calorie is the heat energy required to raise the temperature of 1 kg of water from 14.5°C to 15.5°C

Question 4

Define temperature and name it's S.I. unit.

Answer

Temperature is a parameter which tells the thermal state of a body (i.e., the degree of hotness or coldness of body). It determines the direction of flow of heat when two bodies at different temperatures are placed in contact.
The S.I. unit of temperature is Kelvin (K).

Question 5

State three differences between heat and temperature.

Answer

Heat	Temperature
Heat is that form of energy which flows from a hot body to a cold body when they are kept in contact.	Temperature is a quantity which determines the direction of flow of heat on keeping the two bodies at different temperatures in contact.
The S.I. unit of heat is joule (J)	The S.I. unit of temperature is kelvin (K).

Heat	Temperature
The amount of heat contained in a body depends on mass, temperature and substance of body.	The temperature of a body depends on the average kinetic energy of it's molecules due to their random motion.

Question 6

State the principle of calorimetry.

Answer

When a hot body is mixed (or is kept in contact) with a cold body, heat energy passes from the hot body to the cold body, till both the bodies attain the same temperature. If no heat is lost to the surrounding then, heat lost by the hot body is equal to the heat gained by the cold body. This is known as the principle of calorimetry.

Question 7

Define the term heat capacity and state it's S.I. unit.

Answer

The term heat capacity of a body is the amount of heat energy required to raise it's temperature by 1° C (or 1 K).
The S.I. unit of heat capacity is joule per kelvin ($J\ K^{-1}$)

Question 8

Define the term specific heat capacity and state it's S.I. unit.

Answer

The specific heat capacity of a substance is the amount of heat energy required to raise the temperature of unit mass of that substance through 1°C (or 1 K). i.e.,

$$\text{Specific heat capacity } c = \frac{\text{Amt of heat energy supplied}}{\text{mass} \times \text{rise in temperature}}$$

The S.I. unit of specific heat capacity is joule per kilogram per kelvin ($J\ kg^{-1}\ K^{-1}$).

Question 9

State three differences between the heat capacity and specific heat capacity.

Answer

Heat capacity	Specific heat capacity
It is the amount of heat energy required to raise the temperature of entire body by 1°C	It is the amount of heat energy required to raise the temperature of unit mass of the body by 1°C.
It depends both on the substance and mass of the body. More the mass of the body more is it's heat capacity.	It does not depend on the mass of the body, but it is the characteristic property of the substance of the body.
S.I. unit is $J\ K^{-1}$	S.I. unit is $J\ kg^{-1}\ K^{-1}$.

Question 10

What do you mean by the following statements —

(i) The heat capacity of a body is 50 $J\ K^{-1}$?

(ii) The specific heat capacity of copper is 0.4 $J\ g^{-1}\ K^{-1}$?

Answer

(i) "The heat capacity of a body is 50 $J\ K^{-1}$" means 50 J of heat energy is required to raise the temperature of that body by 1 K.

(ii) "The specific heat capacity of copper is 0.4 $J\ g^{-1}\ K^{-1}$" means that the heat energy required to raise the temperature of 1 g of copper by 1 K is 0.4 J.

Question 11

Specific heat capacity of a substance A is 3.8 J g^{-1} K^{-1} and of substance B is 0.4 J g^{-1} k^{-1}. Which substance is a good conductor of heat? How did you arrive at your conclusion?

Answer

B is a good conductor of heat energy. **For the same heat energy and same mass, the rise in temperature of B will be more hence, B is a good conductor of heat**.

Question 12

Name two factors on which the heat energy librated by a body on cooling depends.

Answer

The factors on which the heat energy liberated by a body on cooling depends are:

1. Mass of the body
2. Temperature of the body.

Question 13

Name three factors on which the heat energy absorbed by a body depends and state how does it depend on them.

Answer

Three factors on which the heat energy absorbed by a body depends are:

1. **Mass of the body** — Heat energy absorbed by a body is directly proportional to the mass of the body i.e., $Q \propto m$.
2. **Increase in temperature of the body** — Heat energy absorbed is directly proportional to the rise in temperature i.e., $Q \propto \Delta t$.
3. **The material of the body** — Heat energy absorbed by a body depends on the substance of the object which is expressed in terms of it's specific heat capacity c i.e., $Q \propto c$.

Question 14

Two blocks P and Q of different metals having their mass in the ratio 2 : 1 are given same amount of heat. Their temperature rises by same amount. Compare their specific heat capacities.

Answer

Let,

Specific heat capacity of block P = C_p

Specific heat capacity of block Q = C_Q

From relation,

$$c = \frac{Q}{m \times \Delta t}$$

where, c = specific heat capacity

m = mass

Q = heat energy

Δt = change in temperature

Now,

$$\frac{C_p}{C_Q} = \frac{\frac{Q}{2m \times \Delta t}}{\frac{Q}{m \times \Delta t}} \frac{C_p}{C_Q} = \frac{m \times \Delta t}{2m \times \Delta t} \Rightarrow \frac{C_p}{C_Q} = \frac{1}{2}$$

Hence, **the required ratio is 1 : 2**

Question 15

What is the principle of method of mixture ? What other name is given to it? Name the law on which this principle is based.

Answer

Heat energy lost by the hot body = Heat energy gained by the cold body. This is called the principle of method of mixture.

The other name given to it is the **principle of calorimetry**.

This principle is based on **the law of conservation of energy**.

Question 16

Why do the farmers fill their fields with water on a cold winter night?

Answer

On a cold winter night, if the atmospheric temperature falls below 0° C, water in the fine capillaries of plants will freeze, so the veins will burst due to the increase in volume of water on freezing. As a result, plants will die and the crop will get destroyed. In order to save crop on such cold nights, farmers fill their fields with water because water has a high specific heat capacity, so it does not allow the temperature in the surrounding area of plants to fall up to 0° C.

Question 17

Water is used in hot water bottles for fomentation. Give reason.

Answer

Hot water bottles are used for fomentation because water does not cool quickly due to it's high specific heat capacity, so a hot water bottle provides more heat energy for fomentation over a longer period. Hence, water is used in hot water bottles for fomentation.

Question 18

What property of water makes it an effective coolant?

Answer

Water is an effective coolant. By allowing water to flow in pipes around the heated parts of a machine, heat energy from such parts is removed. Water in pipes can extract more heat from the surroundings without much rise in it's temperature because of it's high specific heat capacity. This is why radiators in car and generator use water for cooling.

Question 19

Why the base of a cooking pan made thick and heavy?

Answer

The base of a cooking pan is made thick and heavy because it's heat capacity becomes large due to which it gets heated slowly and it imparts sufficient heat energy at a slow rate to the food for it's proper cooking and after cooking it keeps the food warm for a long time.

Exercise 11(A) — Long Questions

Question 1

A mass m_1 of a substance of specific heat capacity c_1 at temperature t_1 is mixed with a mass m_2 of other substance of specific heat capacity c_2 at a lower temperature t_2. Deduce the expression for the temperature t of the mixture. State the assumption made, if any.

Answer

Let a substance A of mass m_1, specific heat capacity c_1 at temperature t_1 is mixed with another substance B of mass m_2, specific heat capacity c_2 at a lower temperature t_2.

If the final temperature of the mixture becomes t, then

Fall in temperature of substance A = $t_1 - t$

Rise in temperature of substance B = $t - t_2$

Heat energy lost by A = $m_1 \times c_1 \times$ fall in temperature

$= m_1c_1 (t_1 - t)$

Heat energy gained by B = $m_2 \times c_2 \times$ rise in temperature

$= m_2c_2 (t - t_2)$

If no heat energy is lost in the surrounding, then by the principle of mixtures,

Heat energy lost by A = Heat energy gained by B

$m_1c_1 (t_1 - t) = m_2c_2 (t - t_2)$

$m_1 c_1 t_1 - m_1c_1 t = m_2 c_2 t - m_2 c_2 t_2$

$m_1c_1 t_1 + m_2c_2 t_2 = m_1c_1 t + m_2c_2 t$

$m_1c_1 t_1 + m_2c_2 t_2 = t (m_1c_1 + m_2c_2)$

Therefore,

$$t = \frac{m_1c_1t_1 + m_2c_2t_2}{m_1c_1 + m_2c_2}$$

The assumption made here is that **there is no loss of heat energy**.

Question 2

Discuss the role of high specific heat capacity of water with reference to climate in coastal areas.

Answer

The specific heat capacity of water is very high. It is about five times as high as that of sand. Hence, the heat energy required for the same rise in temperature by a certain mass of water will be nearly five times than that required by the same mass of sand. Similarly, a certain mass of water will impart nearly five times more heat energy than that given by the same mass of sand for the same fall in temperature.

As such sand (or earth) gets heated or cooled more rapidly as compared to water under the similar conditions (exposure to the Sun). Thus, near the sea shore, there becomes a large difference in temperature between the land and sea due to which convection currents are set up. The cold air from the land blows towards the sea during the night (i.e., land breeze) and during the day cold air blows from the sea towards the land (i.e., sea breeze). These breezes near the sea makes the climate in coastal areas moderate.

Question 3

(a) What is calorimeter?

(b) Name the material of which it is made of. Give two reasons for using the material stated by you.

(c) Out of the three metals A, B and C of specific heat 900 J kg^{-1} $°C^{-1}$, 380 J kg^{-1} $°C^{-1}$ and 460 J kg^{-1} $°C^{-1}$ respectively, which will you prefer for calorimeter? Given reason.

(d) How is the loss of heat due to radiation minimized in a calorimeter?

Answer

(a) A calorimeter is a cylindrical vessel which is used to measure the amount of heat gained (or lost) by a body when it is mixed with the other body.

(b) It is made up of a thin sheet of **copper.** The reasons for using copper are:

1. Copper is a **good conductor of heat**, so the vessel soon acquires the temperature of it's contents.
2. Copper has the **low specific heat capacity** so the heat capacity of calorimeter is low and the amount of heat energy taken by the calorimeter from the contents to acquire it's temperature, is very small.

(c) Heat capacity of the calorimeter should be low. Hence, B should be preferred for making the calorimeter.

(d) The outer and inner surfaces of the vessel should be polished so as to reduce the loss of heat due to radiation in a calorimeter.

Exercise 11(A) — Numericals

Question 1

By imparting heat to a body, it's temperature rises by 15°C. What is the corresponding rise in temperature on the Kelvin scale?

Answer

A degree (or temperature difference) is same on both the celsius and kelvin scales i.e., $\triangle t°$ C = $\triangle T$ K. Therefore, the corresponding rise in temperature on the Kelvin scale will be 15 K.

Question 2

(a) Calculate the heat capacity of a copper vessel of mass 200 g if the specific heat capacity of copper is 410 J kg^{-1} K^{-1}.

(b) How much heat energy will be required to increase the temperature of the vessel in part (a) from 25°C to 35°C?

Answer

(a) Given,

mass (m) = 200 g = 0.20 kg

specific heat capacity (c) = 410 J kg^{-1} K^{-1}

We know that,

Heat capacity (C') = Mass (m) × specific heat capacity (c)

Substituting the values in the formula above we get, C' = 0.20 x 410 = 82 J K^{-1}

Hence, **heat capacity of a copper vessel = 82 J K^{-1}**

(b) Change in temperature = 35°C - 25°C = 10°C = 10 K

Energy required to increase the temperature of vessel Q = ?

From relation,

Q = m x c x △T

Substituting the values in the formula above we get,

Q = 0.20 x 410 x 10 = 820 J

Hence, **heat energy required to increase the temperature of the vessel = 820 J**

Question 3

A piece of iron of mass 2.0 kg has a heat capacity of 966 J K^{-1} . Find (i) heat energy needed to warm it by 15° C, and (ii) it's specific heat capacity in S.I unit.

Answer

(i) Given,

mass (m) = 2.0 kg

heat capacity (C') = 966 J K^{-1}

rise in temperature (△t) = 15°C

Heat energy needed (Q) = ?

From relation,

Q = C' × △t

Substituting the values in the formula above we get,

Q = 966 x 15 = 14,490 J

Hence, **heat energy needed to warm it by 15°C = 14,490 J**

(ii) specific heat capacity (c) = ?

We know that,

$$c = \frac{C'}{m}$$

Substituting the values in the formula above we get,

$$c = \frac{966}{2} = 483 \text{ J kg}^{-1}\text{K}^{-1}$$

Hence, **Specific heat capacity = 483 J kg^{-1} K^{-1}**

Question 4

Calculate the amount of heat energy required to raise the temperature of 200 g of copper from 20°C to 70°C. Specific heat of capacity of copper = 390 J kg^{-1} K^{-1}

Answer

Given,

Mass of copper (m) = 200 g = 0.2 kg

Change of temperature (△t) = (70 - 20)°C = 50°C

Specific heat capacity of copper (c) = 390 J kg^{-1} K^{-1}

Amount of heat required to raise the temperature of 0.2 kg of copper = ?

From relation,

Q = m x c x △t

Substituting the values in the formula above we get,

Q = 0.2 x 390 x 50 = 3900 J

Hence, **the amount of heat energy required to raise the temperature of 200 g of copper from 20° C to 70° C = 3900 J**

Question 5

1300 J of heat energy is supplied to raise the temperature of 0.5 kg of lead from 20° C to 40° C. Calculate the specific heat capacity of lead.

Answer

Given,

Heat energy supplied (Q) = 1300 J

Mass of lead (m) = 0.5 kg

Change in temperature (△t) = (40 – 20)°C = 20° C

Specific heat capacity (c) = ?

From relation,

$$Q = m \times c \times \triangle t$$

Substituting the values in the formula above we get,

$$1300 = 0.5 \times c \times 20 \Rightarrow c = \frac{1300}{0.5 \times 20} \Rightarrow c = 130 \text{ J kg}^{-1}\text{K}^{-1}$$

Hence, **specific heat capacity of lead = 130 J kg^{-1} K^{-1}**

Question 6

A car's cooling system uses water to absorb heat from the engine. If 5 kg of water absorbs 420 kJ of heat, what is the temperature increase of water? (Specific heat capacity of water = 4200 J kg^{-1} K^{-1})

Answer

Given,

Mass of water (m) = 5 kg

Heat absorbed (Q) = 420 kJ = 420 × 10^3 J

Specific heat capacity of water (c) = 4200 J kg^{-1} K^{-1}

Let, increase in temperature be △t.

From relation,

$$Q = mc\triangle t$$

On rearranging terms,

$$\triangle t = \frac{Q}{mc}$$

Substituting the values in the formula above we get,

$$\triangle t = \frac{420 \times 10^3}{5 \times 4200} = \frac{100}{5} = 20K = 20 \quad {}^{o}C$$

Temperature of water will increase by 20 °C.

Question 7

Find the time taken by a 500 W heater to raise the temperature of 50 kg of material of specific heat capacity 960 J kg^{-1} K^{-1}, from 18°C to 38°C. Assume that all the heat energy supplied by heater is given to the material.

Answer

Given,

Power of heater (P) = 500 W

mass of material (m) = 50 kg

Specific heat capacity of material (c) = 960 J kg^{-1} K^{-1}

Change in temperature △t = (38 – 18)°C = 20° C = 20 K

From relation,

$$Q = mc\triangle t$$

Substituting the values in the formula above we get,

$$Q = 50 \times 960 \times 20 \Rightarrow Q = 960{,}000$$

Now,

$$Q = \text{Power} \times \text{time}$$

Substituting the values in the formula above we get

$$960{,}000 = 500 \times \text{time} \Rightarrow \text{time} = \frac{960{,}000}{500} \Rightarrow \text{time} = 1920 \text{ s} = 32 \text{ min}$$

Hence, **time taken = 32 min**

Question 8

A fire truck uses 10,000 litres of water to extinguish a fire, cooling down the burning material from 500°C to 100°C. If the temperature of water increases by 40°C, how much heat energy is absorbed by it? (Specific heat capacity of water = 4200 J kg^{-1} K^{-1})

Answer

Given,

Volume of water (V) = 10,000 L

Temperature increased (△t) = 40°C = 40 K

Specific heat capacity of water (c) = 4200 J kg^{-1} K^{-1}

As,

Density of water (d) = 1 Kg/L

$$d = \frac{m}{V} \Longrightarrow m = dV = 1 \times 10000 = 10000 \text{ kg}$$

Let, Heat absorbed is Q.

From relation,

$$Q = mc\triangle t$$

Substituting the values in the above formula, $Q = 10{,}000 \times 4200 \times 40 = 168 \times 10^7 J$

Heat absorbed by water is 168 x 10^7 J.

Question 9

An electric heater of power 600 W raises the temperature of 4.0 kg of a liquid from 10.0° C to 15.0° C in 100 s. Calculate — (i) the heat capacity of 4.0 kg of liquid, and (ii) the specific heat capacity of liquid.

Answer

(i) Power of heater (P) = 600 W

Mass of liquid (m) = 4.0 kg

Change in temperature of liquid = (15 – 10)°C = 5° C (or 5 K)

Time taken to raise it's temperature (t) = 100 s

heat capacity = ?

From relation,

$$Q = \text{Power} \times \text{time}$$

Substituting the values in the formula above we get,

$$Q = 600 \times 100 \Rightarrow Q = 60000J$$

Now,

$$C\ ' = \frac{Q}{\triangle T}$$

Substituting the values in the formula above we get,

$$C\ ' = \frac{60{,}000}{5} C\ ' = 1.2 \times 10^4 \text{ JK}^{-1}$$

Hence, **heat capacity = 1.2 x 10 J K^{-1}**

(ii) specific heat capacity {c} = ?

$$c = \frac{Q}{m \times \triangle T}$$

Substituting the values in the formula above we get,

$$c = \frac{60000}{4 \times 5} c = \frac{60000}{4 \times 5} c = 3 \times 10^3 \text{ J kg}^{-1}\text{K}^{-1}$$

Hence, **specific heat capacity = 3 x 10^3 J Kg^{-1} K^{-1}**

Question 10

0.5 kg of lemon squash at 30°C is placed in a refrigerator which can remove heat at an average rate of 30 J s^{-1}. How long will it take to cool the lemon squash to 5°C ? Specific heat capacity of squash = 4200 J kg^{-1} K^{-1}.

Answer

Given,

mass (m) = 0.5 kg

Change in temperature = (30 – 5)°C = 25° C = 25 K

Specific heat capacity of squash (c) = 4200 J kg^{-1} K^{-1}

From relation,

$$Q = m \times c \times \triangle T$$

Substituting the values in the formula above we get,

$$Q = 0.5 \times 4200 \times 25 \Rightarrow Q = 52{,}500 J$$

Let time taken to remove 52500 J of heat be t.

Now it is given that,

30 J of heat is removed in 1 sec

So, 52500 J of heat ⇒ t = ?

$$t = \frac{1}{30} \times 52{,}500 \Rightarrow t = 1750 \text{ s} \Rightarrow t = 29 \text{ min } 10 \text{ sec}$$

Hence, **time taken = 29 min 10 sec**

Question 11

A mass of 50 g of a certain metal at 150°C is immersed in 100 g of water at 11°C. The final temperature is 20°C. Calculate the specific heat capacity of the metal. Assume that the specific heat capacity of water is 4.2 J g^{-1} K^{-1}.

Answer

Given,

Mass of metal (m) = 50 g

Fall in temperature of metal = (150 – 20) = 130°C

Rise in temperature of water = (20 - 11) = 9°C

Heat energy given by metal = mc△t

= 50 x c x 130

= 6500 x c **[Equation 1]**

Heat energy taken by water = 100 × 4.2 × 9

= 3780 **[Equation 2]**

Assuming that there is no loss of heat energy,

Heat energy given by metal = Heat energy taken by water.

Equating equations 1 & 2, we get,

$$6500 \times c = 3780 c = \frac{3780}{6500} c = 0.582 \text{ J g}^{-1}\text{K}^{-1}$$

Hence, **specific heat capacity of the metal = 0.582 J g^{-1} K^{-1}**

Question 12

45 g of water at 50°C in a beaker is cooled when 50 g of copper at 18°C is added to it. The contents are stirred till a final constant temperature is reached. Calculate the final temperature. The specific heat capacity of copper is 0.39 J g^{-1} K^{-1} and that of water is 4.2 J g^{-1} K^{-1}. State the assumptions used.

Answer

Given,

Mass of water = 45 g

Let the final constant temperature reached be t°C

Fall in temperature of water = (50 – t)°C

Mass of copper = 50 g

Rise in temperature of copper = (t - 18)°C

The specific heat capacity of the copper $c_c = 0.39$ J g^{-1} K^{-1}
The specific heat capacity of water $c_w = 4.2$ J g^{-1} K^{-1}
Heat energy given by water = mc△t
= 45 x 4.2 x (50 – t) **[Equation 1]**
Heat energy taken by copper = 50 x 0.39 x (t - 18) **[Equation 2]**
Assuming that there is no loss of heat energy
Heat energy given by water = Heat energy taken by copper
Equating equations 1 & 2, we get,

$$45 \times 4.2 \times (50 - t) = 50 \times 0.39 \times (t - 18) \Rightarrow 189 \times (50 - t) = 19.5 \times (t - 18) \Rightarrow (189 \times 50) - (189 \times t)$$
$$= (19.5 \times t) - (19.5 \times 18) \Rightarrow (9450) - (189 \times t)] = (19.5 \times t) - (351) \Rightarrow 9450 + 351$$
$$= (19.5t) + (189t) \Rightarrow 9801 = (208.5t) \Rightarrow t = \frac{9801}{208.5} \Rightarrow t = 47.0072°C \approx 47°C$$

Hence, **final temperature = 47°C**

Question 13

200 g of hot water at 80°C is added to 400 g of cold water at 10°C. Neglecting the heat taken by the container, calculate the final temperature of the mixture of water. Specific heat capacity of water = 4200 J kg^{-1} K^{-1}.

Answer

Mass of hot water = 200 g
Temperature of hot water = 80° C
Mass of cold water = 400 g
Temperature of cold water = 10° C
Let final temperature be t
Fall in temperature of hot water = (80 – t)°C
Rise in temperature of cold water = (t - 10)°C
The specific heat capacity of water $c_w = 4200$ J kg^{-1} K^{-1} = 4.2 J g^{-1} K^{-1}
Heat energy given by hot water = mc△t
= 200 x 4.2 x (80 – t) **[Equation 1]**
Heat energy taken by cold water = 400 x 4.2 x (t - 10) **[Equation 2]**
Assuming that there is no loss of heat energy,
Heat energy given by hot water = Heat energy taken by cold water
Equating equations 1 & 2, we get,

$$200 \times 4.2 \times (80 - t) = 400 \times 4.2 \times (t - 10)2 \times (80 - t) = 4 \times (t - 10)160 - 2t = 4t - 40160 + 40$$
$$= 4t + 2t200 = 6t \Rightarrow t = \frac{200}{6} \Rightarrow t = 33.3°C$$

Hence, **final temperature = 33.3°C**

Questions 14

The temperature of 600 g of cold water rises by 15°C when 300 g of hot water at 50°C is added to it. What was the initial temperature of the cold water?

Answer

Given,
Mass of cold water = 600 g
Mass of hot water = 300 g
Temperature of hot water = 50° C
Let initial temperature of cold water be t_i
Let the final temperature be t
Gain in temperature of cold water = (t - t_i) = 15° C
Loss of heat from hot water = (50 - t)

Heat energy given by hot water = mc△t
= 300 x 4.2 x (50 – t) **[Equation 1]**
Heat energy taken by cold water = 600 x 4.2 x (t - t_i) **[Equation 2]**
Assuming that there is no loss of heat energy
Heat energy given by hot water = heat energy taken by cold water
Equating equations 1 & 2, we get,

$$300 \times 4.2 \times (50 - t) = 600 \times 4.2 \times 15 \Rightarrow 3 \times (50 - t) = 6 \times 15 \Rightarrow 50 - t = 2 \times 15 \Rightarrow 50 - t = 30 \Rightarrow t = 50 - 30 = 20°C$$

final temperature (t) = 20°C
initial temperature = ?
We know,
t - t_i = 15
20 - t_i = 15
Therefore, t_i = 20 - 15 = 5° C
Hence, **initial temperature = 5° C**

Question 15

1.0 kg of water is contained in a 1.25 kW kettle. Calculate the time taken for the temperature of water to rise from 25° C to it's boiling point 100° C. Specific heat capacity of water = 4.2 J g^{-1} K^{-1}.

Answer

Given,
mass = 1 kg = 1000 g
Heat energy taken by water (Q) = mc△t
= 1000 x 4.2 x (100 – 25)
= 1000 x 4.2 x 75
= 315000 J
Now,

$$Q = \text{Power} \times \text{time}$$

Substituting the values in the formula above we get,

$$315000 = 1250 \times t \Rightarrow t = \frac{315000}{1250} \Rightarrow t = 252 \text{ sec} = 4 \text{ min } 12 \text{ sec}$$

Hence, **time = 4 min 12 sec**

Exercise 11(B) — Multiple Choice Type

Question 1

Heat energy is .... during melting and it is .... during freezing at a constant temperature.

1. rejected, absorbed
2. rejected, rejected
3. absorbed, absorbed
4. absorbed, rejected

Answer

absorbed, rejected

Reason — Heat energy is absorbed during melting, as the solid absorbs energy to change into a liquid while maintaining a constant temperature.
Heat energy is rejected during freezing, as the liquid releases energy to change into a solid while maintaining a constant temperature.

Question 2

An increase in pressure results in .... in melting point of ice :

1. increase
2. no change

3. decrease
4. none of the above

Answer

decrease

Reason — The melting point of ice decreases when pressure increases because when pressure is increased, volume is decreased and the volume of water is less than ice. So it will be easier to change the state from solid to liquid, and therefore, the melting point decreases.

Question 3

At high altitudes, water boils at a temperature of :

1. 100°C
2. more than 100°C
3. less than 100°C
4. 150°C

Answer

less than 100°C

Reason — At high altitudes, such as hills and mountains, the atmospheric pressure is low (less than one atmospheric pressure), therefore at these places, water boils at temperature lower than 100° C and so it does not provide the required heat energy to it's contents for cooking. Thus, cooking there becomes very difficult and it takes a much longer time.

Question 4

If common salt is added to water, it boils at a temperature of :

1. 100°C
2. lower than 100°C
3. higher than 100°C
4. cannot say

Answer

higher than 100°C

Reason — The boiling point of water increases by addition of salt to it. If common salt is added to water, it boils at a temperature higher than 100° C.

Question 5

The specific latent heat of fusion of water is:

1. 80 Cal g^{-1}
2. 2260 J g^{-1}
3. 80 J g^{-1}
4. 336 J kg^{-1}

Answer

80 Cal g^{-1}

Reason — The specific latent heat of fusion of water is 80 Cal g^{-1}

Question 6

Heat energy supplied during the melting of a substance is utilised in :

1. increasing the kinetic energy of molecules
2. decreasing the potential energy of molecules
3. increasing the potential energy of molecules
4. decreasing the kinetic energy of molecules

Answer

increasing the potential energy of molecules

Reason — When a substance is melting, it transitions from a solid phase to a liquid phase. During this phase transition, the heat energy supplied is used to overcome the forces holding the molecules together in the solid phase.

This process increases the potential energy of the molecules, allowing them to break free from their fixed positions in the crystal lattice. However, the kinetic energy of the molecules remains relatively constant during the phase transition, as the temperature remains constant until the phase change is complete. Therefore, the primary use of heat energy during melting is to increase the potential energy of the molecules

Exercise 11(B) — Very Short Questions

Question 1

Write down the approximate range of temperature at which water boils in a pressure cooker.

Answer

The water boils at about 120° C to 125° C in a pressure cooker.

Question 2

Complete the following sentences:

1. When ice melts, it's volume ....
2. Decrease in pressure over ice .... it's melting point.
3. Increase in pressure .... the boiling point of water.
4. A pressure cooker is based on the principle that boiling point of water increases with the ....
5. The boiling point of water is defined as ....
6. Water can be made to boil at 115°C by .... pressure over it's surface.

Answer

1. When ice melts, it's volume ***decreases***.
2. Decrease in pressure over ice ***increases*** its melting point.
3. Increase in pressure ***increases*** the boiling point of water.
4. A pressure cooker is based on the principle that boiling point of water increases with the ***increase in pressure***
5. The boiling point of water is defined as ***the constant temperature at which water changes to steam***
6. Water can be made to boil at 115°C by ***increasing*** pressure over it's surface.

Question 3

Write the approximate value of specific latent heat of ice.

Answer

The approximate value of specific latent heat of ice is 336 x 10^3 J kg^{-1}

Question 4

1 g ice at 0° C melts to form 1 g water at 0° C. State whether the latent heat is absorbed or given out by ice.

Answer

Latent heat is absorbed by ice when 1 g ice at 0° C melts to form 1 g water at 0° C.

Exercise 11(B) — Short Questions

Question 1

A substance on heating undergoes (i) a rise in it's temperature, (ii) a change in it's phase without change in it's temperature. In each case, state the change in energy of molecules of the substance.

Answer

(i) When a substance on heating undergoes a rise in it's temperature then **average kinetic energy of molecules increases**.

(ii) When a substance on heating undergoes a change in it's phase without change in it's temperature then **average potential energy of molecules increases**.

Question 2

How does the (a) average kinetic energy (b) average potential energy of molecules of a substance change during it's change in phase at a constant temperature, on heating?

Answer

(a) The average kinetic energy of molecules **does not change** during it's change in phase at a constant temperature, on heating.

(b) **Average potential energy of molecules increases** during it's change in phase at a constant temperature, on heating.

Explanation: During the change in phase of the substance at a constant temperature on heating, the heat supplied is utilized in increasing the separation against the attractive forces between the molecules. This increases the potential energy of the molecules.

As the temperature of the substance remains constant, the average kinetic energy of the molecules does not change. The heat energy supplied during melting is utilised only in increasing the potential energy of the molecules and is called the latent heat of melting.

Question 3

State the effect of presence of impurity on the melting point of ice. Give one use of it.

Answer

The melting point of a substance **decreases** by the presence of impurities in it. The melting point of ice decreases from 0 ° C to -22 ° C on mixing salt to it in proper proportion. This fact is utilized in making the freezing mixture by adding salt to ice. The freezing mixture is used in preparing 'kulfis'.

Question 4

State the effect of increase of pressure on the melting point of ice.

Answer

The melting point of the substances which contract on melting (like ice) decreases by the increase in pressure. For example, the melting point of ice decreases by 0.0072°C for every one atmosphere rise in pressure.

Question 5

How is the boiling point of water affected when some salt is added to it?

Answer

The boiling point of water increases by addition of salt to it. If common salt is added to water, it boils at a temperature higher than 100° C.

Question 6

What is the effect of increase in pressure on the boiling point of a liquid?

Answer

The boiling point of a liquid increases with the increase in pressure.

Question 7

Water boils at 120° C in a pressure cooker. Explain the reason.

Answer

The boiling point of liquid increases with the increase in pressure and decreases with the decrease in pressure. The boiling point of pure water at one atmospheric pressure is 100° C.

In a pressure cooker, steam is not allowed to escape out. The vapour pressure on water inside the cooker becomes nearly 1.75 times the atmospheric pressure, so water boils in it at about 120° C to 125° C due to increased pressure.

Question 8

It is difficult to cook vegetables on hills and mountains. Explain the reason.

Answer

At high altitudes, such as hills and mountains, the atmospheric pressure is low (less than one atmospheric pressure), therefore at these places, water boils at temperature lower than 100° C and so it does not provide the required heat energy to it's contents for cooking. Thus, cooking there becomes very difficult and it takes a much longer time.

Question 9

What do you understand by the term latent heat?

Answer

Heat energy absorbed or liberated in change of phase that is not externally manifested by any rise or fall in temperature is called the **latent heat**.

Question 10

Define the term specific latent heat of fusion of ice. State it's S.I. unit.

Answer

The specific latent heat of fusion of ice is the heat energy required to melt unit mass of ice at 0° C to water at 0° C without any change in temperature.

S.I. unit of latent heat of fusion is J kg^{-1}

Question 11

'The specific latent heat of fusion of ice is 336 J g^{-1}'. Explain the meaning of this statement.

Answer

'The specific latent heat of fusion of ice is 336 J g^{-1}' means 1 g of ice at 0° C absorbs 336 J of heat energy to convert into water at 0° C.

Question 12

Which has more heat: 1 g of ice at 0° C or 1 g of water at 0° C ? Give reasons.

Answer

1 g of water at 0° C has more heat because 1 g of water at 0° C liberates 80 cal heat to form 1 g of ice at 0° C.

Question 13

(a) Which requires more heat: 1 g ice at 0° C or 1 g water at 0° C to raise it's temperature to 10° C ?

(b) Explain your answer in part (a).

Answer

(a) 1 g ice at 0° C requires more heat to raise it's temperature to 10° C.

(b) 1 g ice at 0° C requires more heat to raise it's temperature to 10° C because 1 g ice at 0° C first absorbs 336 J heat to convert into 1 g water at 0° C and then the water absorbs heat to raise it's temperature from 0° to 10° C.

Question 14

Ice cream appears colder to the mouth than water at 0° C. Give reasons.

Answer

Ice cream absorbs heat energy as well as the latent heat while water absorbs only heat energy. Therefore, ice cream absorbs more amount of energy from the mouth as compared to water. Hence, ice cream appears colder to the mouth than water at 0° C.

Question 15

The soft drink bottles are cooled by (i) ice cubes at 0° C, and (ii) iced-water at 0° C. Which will cool the drink quickly? Give reason.

Answer

Ice cubes at 0°C will cool the soft drink bottles more quickly than iced-water at 0°C.

1 g of ice at 0° C takes 336 J of heat energy from the drink to melt into water at 0° C. Thus, the drink liberates an additional 336 J of heat energy to 1 g ice at 0° C than to 1 g ice-cold water at 0° C. Therefore, cooling produced by 1 g ice at 0° C is much more than that by 1 g water at 0° C.

Question 16

It is generally cold after a hail storm than during and before the hail storm. Give reasons.

Answer

It is generally cold after a hail storm than during and before it because after the hail storm, ice absorbs the heat energy required for it's melting from the surroundings, so the temperature of the surrounding falls further down and we feel more cold.

Question 17

The temperature of surroundings starts falling when ice in a frozen lake starts melting. Give reasons.

Answer

The temperature of surroundings starts falling when ice in a frozen lake starts melting because quite a large amount of heat energy is required for melting the frozen lake which is absorbed from the surrounding atmosphere. As a result, the temperature of the surrounding falls and it becomes very cold.

Question 18

Water in lakes and ponds do not freeze at once in cold countries. Give reason.

Answer

Water in lakes and ponds do not freeze at once in cold countries because the specific latent heat of fusion of ice is sufficiently high (= 336 J g^{-1}). The water in lakes and ponds will have to liberate a large quantity of heat to the surrounding before freezing. The layer of ice formed over the water surface, being a poor conductor of heat, will also prevent the loss of heat from the water of lake, hence the water does not freeze all at once.

Exercise 11(B) — Long Questions

Question 1

(a) What do you understand by the change of phase of a substance?
(b) Is there any change in temperature during the change of phase?
(c) Does the substance absorb or liberate any heat during the change of phase?
(d) What is the name given to the energy absorbed during a phase change?

Answer

(a) The process of **change from one state to another at a constant temperature** is called the change of phase.
(b) **No**, there is no change in temperature during the change of phase.
(c) **Yes**, the substance absorb or liberates heat during the change of phase. The heat is absorbed during melting and it is liberated during freezing at a constant temperature.
(d) The name given to the energy absorbed during a phase change is **latent heat**.

Question 2

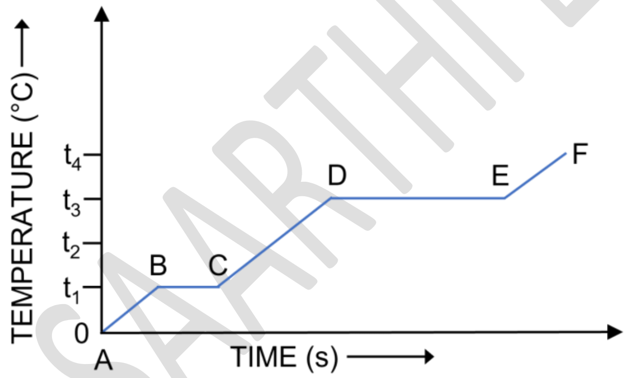
A substance changes from it's solid state to the liquid state when heat is supplied to it
(a) Name the process.
(b) What name is given to heat absorbed by the substance.
(c) How does the average kinetic energy of molecules of the substance change.

Answer

(a) The process is known as melting.
(b) The heat absorbed by the substance is called the **latent heat of melting**.
(c) The average kinetic energy of the molecules **does not change** as there is no change in temperature.

Question 3

The diagram below shows the change of phases of a substance on a temperature-time graph on heating the substances at a constant rate.



(a) What do parts AB, BC, CD and DE represent?
(b) What is the melting point of the substance?
(c) What is the boiling point of the substance?

Answer

(a) The different parts represent the following:

- Part AB — It shows the **rise in temperature of solid from 0°C to t_1°C**.
- Part BC — It shows **melting at temperature t_1°C**.
- Part CD — It shows the **rise in temperature of liquid from t_1°C to t_3°C**.
- Part DE — It shows **boiling at temperature t_3°C**

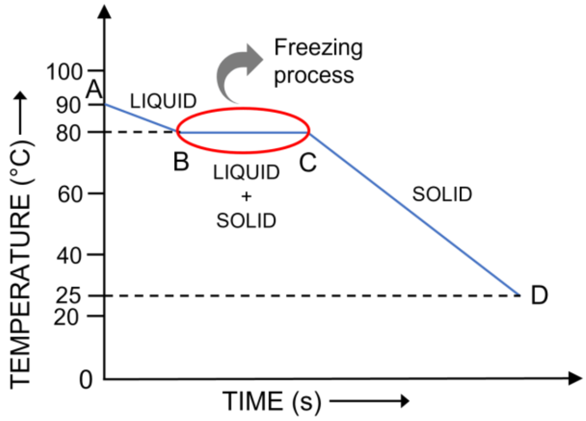
(b) The melting point of the substance is **t_1° C**.
(c) The boiling point of the substance is **t_3° C**.

Question 4

The melting point of naphthalene is 80° C and the room temperature is 25°. A sample of liquid naphthalene at 90° is cooled down to room temperature. Draw a temperature-time graph to represent this cooling. On the graph mark the region which corresponds to the freezing process.

Answer

Temperature-time graph representing the cooling of naphthalene from 90°C to room temperature of 25°C is shown below:

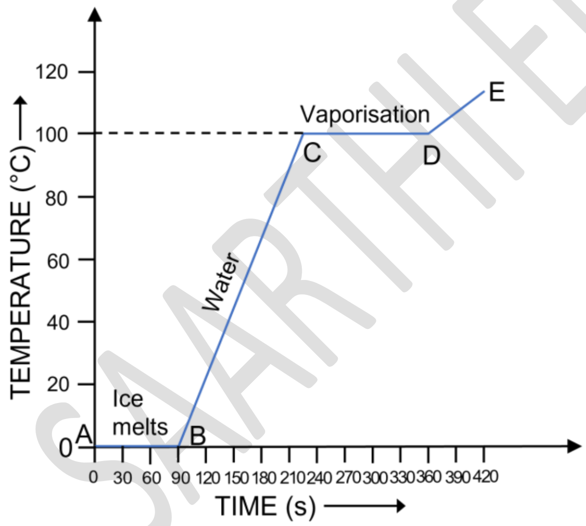


Question 5

1 kg of ice at 0°C is heated at a constant rate and it's temperature is recorded every 30 s till steam is formed at 100°C. Draw a temperature-time graph to represent the change of phases.

Answer

Temperature-time graph representing the change of phases when ice is heated till steam is formed at 100°C is shown below:



Question 6

Explain the terms boiling and boiling point. How is the volume of water affected when it boils at 100°C.

Answer

The change from liquid to gas (or vapour) phase on absorption of heat at a constant temperature is called **boiling or vaporisation**.

The particular temperature at which vaporisation occurs is known as the **boiling point** of liquid.

Volume of water increases when it boils at 100° C. 1 cm^3 of water at 100 ° C becomes 1760 cm^3 of steam at 100 ° C.

Question 7

Explain the following —

(a) The surroundings become pleasantly warm when water in a lake starts freezing in cold countries.

(b) The heat supplied to a substance during it's change of state, does not cause any rise in it's temperature.

Answer

(a) The surroundings become pleasantly warm when water in a lake starts freezing in cold countries because the specific latent heat of fusion of ice is very high, hence large quantity of heat is released when the water in the lake freezes. Therefore, the temperature of the surrounding becomes pleasantly warm.

(b) During the change in phase of the substance at a constant temperature on heating, the heat supplied is utilized in increasing the separation against the attractive forces between the molecules. This increases the potential energy of the molecules.

The average kinetic energy of the molecules does not change. Hence, the temperature of the substance remains constant. The heat energy supplied during melting is utilised only in increasing the potential energy of the molecules and is called the latent heat of melting.

Exercise 11(B) — Numericals

Question 1

20 g of ice at 0° C absorbs 10,920 J of heat energy to melt and change to water at 50° C. Calculate the specific latent heat of fusion of ice. Specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

Answer

Given,

Mass (m) = 20 g

Heat energy absorbed (Q) = 10,920 J

Specific heat capacity of water = 4200 J kg^{-1} K^{-1} = 4.2 J g^{-1} K^{-1}

Specific latent heat of fusion of ice (L) = ?

(i) Heat energy required to melt the ice at 0° C to water at 0° C (Q_1) = m x L

Substituting the values in the formula we get,

$$Q_1 = 20 \times L$$

(ii) Heat energy required to raise temperature from 0° C to 50° C = m x c x rise in temperature

Substituting the values in the formula we get,

$$Q_2 = 20 \times 4.2 \times 50 = 4200 \text{ J}$$

From relation,

$$Q = Q_1 + Q_2 10{,}920 = (20 \times \text{ L}) + 420010{,}920 - 4200 = 20 \times L6720 = 20 \times L \Rightarrow L = \frac{6720}{20} \Rightarrow L = 336 \text{ J g}^{-1}$$

Hence, **Specific latent heat of fusion of ice = 336 J g^{-1}**

Question 2

How much heat energy is released when 500 g of water at 80° C cools down to 0° C and then completely freezes? [specific heat capacity of water = 4.2 J g^{-1} K^{-1}, specific latent heat of fusion of ice = 336 J g^{-1}].

Answer

Given,

Mass (m) = 500 g

Specific heat capacity of water (c) = 4.2 J g^{-1} K^{-1}

Specific latent heat of fusion of ice (L) = 336 J g^{-1}

(i) Heat energy released when water lowers it's temperature from 80° C to 0° C

= m x c x change in temperature

Substituting the values in the formula we get,

Q_1 = 500 x 4.2 x (80 - 0)

= 500 x 4.2 x 80

= 168 x 10^3 J

(ii) Heat energy released when water at 0° C changes into ice at 0° C = m x L
Substituting the values in the formula we get,
Q_2 = 500 x 336
= 168 x 10^3 J
From relation,
Q = Q_1 + Q_2
= 168 x 10^3 J + 168 x 10^3 J
= 336 x 10^3 J
Total heat released = 336 x 10^3 J
Question 3
A molten metal of mass 150 g is kept at it's melting point 800° C. When it is allowed to freeze at the same temperature, it gives out 75,000 J of heat energy.
(a) What is the specific latent heat of the metal?
(b) If the specific heat capacity of metal is 200 J kg^{-1} K^{-1}, how much additional heat energy will the metal give out in cooling to - 50° C?
Answer
(a) Given,
Mass (m) = 150 g
Heat energy given out (Q) = 75,000 J
Specific latent heat of the metal = ?
From relation Q = m x L
Substituting the values in the formula we get,

$$75000 = 150 \times L \Rightarrow L = \frac{75000}{150} \Rightarrow L = 500 \text{ J g}^{-1}$$

Hence, the specific latent heat of the metal = 500 J g^{-1}
(b) Specific heat capacity of metal is 200 J kg^{-1} K^{-1}
Change in temperature
= 800 – (-50) = 800 + 50 = 850° C = 850 K
From relation,
Q = m x c x change in temperature
Substituting the values we get,

$$Q = 0.15 \times 200 \times 850 Q = 25{,}500 J$$

Hence, 25,500 J of heat energy will be given out
Question 4
A solid metal of mass 150 g melts at it's melting point of 800° C by providing heat at the rate of 100 W. The time taken for it to completely melt at the same temperature is 4 min. What is the specific latent heat of fusion of the metal?
Answer
Given,
m = 150 g = 0.15 kg
P = 100 W
t = 4 min = 240 s
specific latent heat of fusion of the metal = ?
Heat supplied = P x t
Substituting the values we get,

$$\text{Heat supplied} = 100 \times 240 \text{Heat supplied} = 24000 J$$

We know,
Q = m x L
Substituting the values we get,

$$24000 = 0.15 \times L \Rightarrow L = \frac{24000}{0.15} \Rightarrow L = 160,000 \Rightarrow L = 1.6 \times 10^5 \text{ J kg}^{-1}$$

Hence, **specific latent heat of fusion of the metal = 1.6 x 10^5 J kg^{-1}**

Question 5

A refrigerator converts 100 g of water at 20° C to ice at -10° C in 73.5 min. Calculate the average rate of heat extraction in watt. The specific heat capacity of water is 4.2 J g^{-1} K^{-1} , specific latent heat of ice is 336 J g^{-1} and the specific heat capacity of ice is 2.1 J g^{-1} K^{-1}.

Answer

Given,
mass (m) = 100 g
time (t) = 73.5 min
specific heat capacity of water = 4.2 J g^{-1} K^{-1}
specific latent heat of ice = 336 J g^{-1}
specific heat capacity of ice = 2.1 J g^{-1} K^{-1}
Heat energy released by water in fall of it's temperature from 20° to 0° C (Q_1)
= mass x specific heat capacity x fall in temperature
= 100 × 4.2 x (20 - 0)
= 100 × 4.2 x 20
= 8400 J
Hence, Q_1 = 8400 J
Heat energy released by water when it converts into ice at 0° C (Q_2) = m x L_{ice}
= 100 × 336
= 33600 J
Heat energy released when ice cools from 0° C to -10° C (Q_3) = m x c x change in temperature
= 100 × 2.1 x [0 - (-10)]
= 100 x 2.1 x 10
= 2100 J
Hence,
Total heat energy = Q_1 + Q_2 + Q_3
= 8400 + 33600 + 2100
= 44100 J
Time taken = 73.5 min = 4410 s
Average rate of heat extraction (P)

$$P = \frac{E}{t}$$

Substituting the values in the formula we get,

$$P = \frac{44100}{4410} P = 10W$$

Hence, average rate of heat extraction = 10 W

Question 6

In an experiment, 17 g of ice is used to bring down the temperature of 40 g of water at 34° C to it's freezing temperature. The specific heat capacity of water is 4.2 J g^{-1} K^{-1}. Calculate the specific latent heat of ice. State one important assumption made in the above calculation.

Answer

Given,
Mass of ice (m_1) = 17 g
Mass of water (m_2) = 40 g
Change in temperature = 34 – 0 = 34° C = 34 K
Specific heat capacity of water (c) = 4.2 J g^{-1} K^{-1}

specific latent heat of ice = ?
Assuming that no heat energy is lost,
heat energy required by ice to melt = heat energy given by water
So,
m_1 x L = m_2 x c x change in temperature
Substituting the values in the relation above we get,

$$17 \times L = 40 \times 4.2 \times 3417 \times L = 5712 \Rightarrow L = \frac{5712}{17} \Rightarrow L = 336 \text{ J g}^{-1}$$

Hence, **specific latent heat of ice = 336 J g^{-1}**
Assumption — **There is no loss of energy**.
Question 7
The temperature of 170 g of water at 50° C is lowered to 5° C by adding certain amount of ice to it. Find the mass of ice added. Given : specific heat capacity of water = 4200 J kg^{-1} K^{-1} and specific latent heat of ice = 336000 J kg^{-1}.
Answer
Given,
m_w = 170 g = 0.17 kg
specific heat capacity of water = 4200 J kg^{-1} K^{-1}
specific latent heat of ice = 336000 J kg^{-1}
m_i = ?
Heat energy given out by water in lowering it's temperature from 50° C to 5° C
= m x c x change in temperature
= 0.17 x 4200 x (50 - 5)
= 0.17 x 4200 x 45
= 32,130
Heat energy taken by m kg ice to melt into water at 0° C
= m_i x L
= m_i x 336000
Heat energy taken by water at 0° C to raise it's temperature to 5° C
= m_i x c x change in temperature
= m_i x 4200 x (5 - 0)
= m_i x 4200 x 5
= m_i x 21000
heat energy released = heat energy taken
Substituting the values we get,

$$32130 = (m_i \times 336000) + (m_i \times 21000)32130 = m_i \times 357000 \Rightarrow m_i = \frac{32130}{357000} \Rightarrow m_i = 0.09 \text{ Kg} = 90 \text{ g}$$

Hence, **the mass of ice added = 90 g**
Question 8
Find the result of mixing 10 g of ice at -10° C with 10 g of water at 10° C. Specific heat capacity of ice = 2.1 J g^{-1} K^{-1}, specific latent heat of ice = 336 J g^{-1}, and specific heat capacity of water = 4.2 J g^{-1} K^{-1}.
Answer
Given,
mass of ice = 10 g
mass of water = 10 g
Specific heat capacity of ice = 2.1 J g^{-1} K^{-1}
specific latent heat of ice = 336 J g^{-1},
specific heat capacity of water = 4.2 J g^{-1} K^{-1}
Let the final temperature be t° C.

Heat energy taken by ice at – 10° C to raise it's temperature to 0° C (Q_1)
= m x c x change in temperature
= 10 x 2.1 x [0 - (-10)]
= 10 x 2.1 x 10
= 210 J
Hence, Q_1 = 210 J
Heat energy taken by ice at 0° C to convert into water at 0° C (Q_2)
= m x L_{ice}
= 10 × 336
= 3360 J
Hence, Q_2 = 3360 J
Heat energy taken by water at 0° C to raise it's temperature to t° C (Q_3) = m x c x change in temperature
= 10 × 4.2 × (t – 0)
= 10 × 4.2 × t
= 42 t
Hence, Q_3 = 42 t
Heat energy released by water at 10° C to lower it's temperature to t° C (Q_4) = m x c_{water} x change in temperature
= 10 × 4.2 × (10 – t)
= 42 × (10 – t) = 420 – 42t
Hence, Q_4 = 420 – 42t
If there is no loss of heat,
Heat energy gained = Heat energy lost

$$210 + 3360 + 42t = 420 - 42t3570 - 420 = -42t - 42t3150 = -84tt = -\frac{3150}{84}t = -37.5°C$$

This cannot be true because water cannot exist at -37.5° C.
Hence, we can say that the whole of the ice did not melt.
Let amount of ice which melts = m g
Final temperature of the mixture = 0° C
Heat energy gained by ice at -10° C to raise it's temperature to 0° C
= m x c_{ice} x change in temperature
= 10 × 2.1 x [0 - (-10)]
= 10 × 2.1 x 10
= 210 J
Heat energy gained by m gm of ice at 0° C to change into water at 0° C
= m × L_{ice}
= m x 336
= 336m J
Heat energy released by 10 g of water at 10° C to lower it's temperature to 0° C
= m x c_{water} x change in temperature
= 10 × 4.2 × (10 – 0)
= 10 × 4.2 × 10 = 420 J
If there is no loss of heat,
Heat energy gained = Heat energy lost

$$210 + 336m = 420 \Rightarrow 336m = 420 - 210 \Rightarrow 336m = 210 \Rightarrow m = \frac{210}{336} \Rightarrow m = 0.625g$$

Hence, **0.625 g of ice will melt and temperature will remain at 0° C**
Question 9

A piece of ice of mass 40 g is added to 200 g of water at 50° C. Calculate the final temperature of water when all the ice has melted. Specific heat capacity of water = 4200 J kg^{-1} K^{-1} and specific latent heat of fusion of ice = 336 x 10^3 J kg^{-1}.

Answer

Given,

m_i = 40 g

m_w = 200 g

Specific heat capacity of water = 4200 J kg^{-1} K^{-1}

specific latent heat of fusion of ice = 336 x 10^3 J kg^{-1}

final temperature of water = ?

Let final temperature = t

Heat energy given out by water when it cools from 50° C to t° C

= m x c x change in temperature

= 200 × 4.2 × (50 – t)

= 42000 – 840t

Heat energy taken by ice when it converts from ice into water at 0° C

= m x L

= 40 × 336 J

= 13440 J

Heat energy taken by water when it raises it's temperature from 0° to t° C

= m x c x change in temperature

= 40 × 4.2 × (t – 0)

= 40 × 4.2 × t

= 168t

If there is no loss of energy,

Heat energy gained = heat energy lost

Substituting the values we get,

$$13440 + 168t = 42000 – 840t 168t + 840t = 42000 – 13440 1008t = 28560 t = \frac{28560}{1008} t = 28.330°C$$

Hence, **final temperature = 28.330° C**

Question 10

Calculate the mass of ice needed to cool 150 g of water contained in a calorimeter of mass 50 g at 32°C such that the final temperature is 5°C. Specific heat capacity of calorimeter = 0.4 J g^{-1} $°C^{-1}$, Specific heat capacity of water = 4.2 J g^{-1} $°C^{-1}$, Latent heat capacity of ice = 330 J g^{-1}.

Answer

Given,

mass of water m_w = 150 g

mass of calorimeter m_c = 50 g

Specific heat capacity of calorimeter = 0.4 J g^{-1} $°C^{-1}$,

Specific heat capacity of water = 4.2 J^{-1} $°C^{-1}$,

Latent heat capacity of ice = 330 J g^{-1}

mass of ice m_i = ?

Heat energy imparted by calorimeter and water contained in it in cooling from 32° C to 5° C is used in melting ice and then raising the temperature of melted ice from 0°C to 5°C.

Heat energy imparted by water (Q_1)

= m x c x change in temperature

= 150 x 4.2 x (32 - 5)

= 150 x 4.2 x 27
= 17,010 J
Heat energy imparted by calorimeter (Q_2)
= m x c x change in temperature
= 50 x 0.4 x (32 - 5)
= 50 x 0.4 x 27
= 540 J
Heat energy taken by ice to melt (Q_3)
= m_i x L
= m_i x 330
Heat energy gained by water from melted ice to reach from 0°C to 5°C (Q_4)
= m_i x c x change in temperature
= m_i x 4.2 x (5 - 0)
= m_i x 4.2 x 5
= m_i x 21
From the principle of calorimetry, if the system is fully insulated then,
Heat gained by cold body = Heat lost by hot body.
$Q_1 + Q_2 = Q_3 + Q_4$
Substituting the values we get,

$$17010 + 540 = (m_i \times 330) + (m_i \times 21) 17550 = m_i \times 351 \Rightarrow m_i = \frac{17550}{351} \Rightarrow m_i = 50g$$

Hence, **mass of ice = 50 g**

Question 11

250 g of water at 30° C is contained in a copper vessel of mass 50 g. Calculate the mass of ice required to bring down the temperature of the vessel and it's contents to 5° C. Given specific latent heat of fusion of ice = 336 x 10^3 J kg^{-1}, specific heat capacity of copper = 400 J kg^{-1} K^{-1}, specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

Answer

Given,
m_{copper} = 50 g
m_{water} = 250 g
Final temperature = 5° C.
Let mass of ice required be m_i.
Heat energy gained by ice at 0° C to convert into water at 0° C
= m_i × L
= m_i x 336 J
Heat energy gained by (m) g of water at 0° C to rise it's temperature to 5° C
= m x c x change in temperature
= m_i x c x (5 - 0) = m_i × 4.2 × 5
= 21 x m_i
Heat energy lost by water at 30° C in cooling to 5° C
= m x c x change in temperature
= 250 × 4.2 × (30 - 5)
= 250 × 4.2 × 25
= 26250 J
Heat energy lost by vessel at 30° C to cool down to 5° C =
= m x c x change in temperature
= 50 × 0.4 × (30 - 5)

= 50 × 0.4 × 25
= 500 J
If there is no loss of heat,
Heat energy gained = Heat energy lost
Substituting the values in the relation above we get,

$$(336 \times m_i) + (21 \times m_i) = 26250 + 500357 \times m_i = 26750 \Rightarrow m_i = \frac{26750}{357} \Rightarrow m_i = 74.93g$$

Hence, **required mass of ice = 74.93 g**

Question 12

2 kg of ice melts when water at 100° C is poured in a hole drilled in a block of ice. What mass of water was used?
Given: Specific heat capacity of water = 4200 J kg^{-1} K^{-1}, specific latent heat of ice = 336 × 10^3 J Kg^{-1}.

Answer

Given,
m_i = 2 kg
Specific heat capacity of water = 4200 J kg^{-1} K^{-1},
Specific latent heat of ice = 336 × 10^3 J Kg^{-1}.
m_{water} = ?
Since the whole block does not melt and only 2 kg of it melts, so final temperature would be 0° C.
Heat energy taken by ice at 0° C to convert into water at 0° C
= m x L
= 2 × 336000
= 672000 J
Initial temperature of water = 100° C
Final temperature of water = 0° C
Heat energy lost by (m_w) kg at 100° C to reach temperature 0° C
= m x c x change in temperature
= m × 4200 × (100 - 0)
= m × 4200 × 100
= 420000 m J
If there is no loss of energy,
heat energy gained = heat energy lost
Substituting the values in the relation above we get,

$$672000 = m \times 420000m = \frac{672000}{420000}m = 1.6kg$$

Hence, **mass of water = 1.6 kg**

Question 13

Calculate the total amount of heat energy required to convert 100 g of ice at -10° C completely into water at 100° C. Specific heat capacity of ice = 2.1 J g^{-1} K^{-1}, specific heat capacity of water = 4.2 J g^{-1} K^{-1}, specific latent heat of ice = 336 J g^{-1}.

Answer

Given,
m = 100 g
Specific heat capacity of ice = 2.1 J g^{-1} K^{-1}
specific heat capacity of water = 4.2 J g^{-1} K^{-1}
specific latent heat of ice = 336 J g^{-1}
total amount of heat energy required = ?
Heat energy taken by ice to raise it's temperature from at –10° C to 0° C
= m x c x change in temperature

= 100 × 2.1 × [0 - (-10)]
= 100 x 2.1 x 10
= 2100 J
Heat energy taken by ice at 0° C to convert into water at 0° C
= m x L
= 100 × 336
= 33600 J
Heat energy taken by water to raise the temperature from 0° C to 100° C
= m x c x change in temperature
= 100 × 4.2 × (100 - 0)
= 100 × 4.2 × 100
= 42000 J
Total heat energy gained is
= 2100 + 33600 + 42000
= 77700 J
= 7.77×10^4 J
Hence, **total amount of heat energy required = 7.77×10^4 J**
Question 14
The amount of heat energy required to convert 1 kg of ice at -10° C completely to water at 100° C is 7,77,000 J. Calculate the specific latent heat of ice. Specific heat capacity of ice = 2100 J kg^{-1} K^{-1}, Specific heat capacity of water is 4200 J kg^{-1} K^{-1}.
Answer
Given,
m = 1 kg
heat energy required = 7,77,000 J
Specific heat capacity of ice = 2100 J kg^{-1} K^{-1}
Specific heat capacity of water = 4200 J kg^{-1} K^{-1}
specific latent heat of ice (L) = ?
Heat energy taken by ice to raise temperature from – 10° C to to 0° C
= m x c x change in temperature
= 1 × 2100 × [0 - (-10)]
= 21000 J
Heat energy gained by ice at 0° C to convert into water at 0° C
= m x L
= 1 x L
= L
Heat energy taken by water to raise it's temperature from 0° C to 100° C
= m x c x change in temperature
= 1 x 4200 x (100 - 0)
= 1 × 4200 × 100
= 4,20,000 J
Total heat energy gained
= 21,000 + L + 4,20,000 = 4,41,000 + L
As,
4,41,000 + L = 7,77,000
L = 7,77,000 – 4,41,000
L = 3,36,000 J kg^{-1}
Hence, **specific latent heat of ice = 3,36,000 J kg^{-1}**

Question 15

200 g of ice at 0° C converts into water at 0° C in 1 minute when heat is supplied to it at a constant rate. In how much time, 200 g of water at 0° C will change to 20° C? Take specific latent heat of ice = 336 J g^{-1}.

Answer

Given,

m_i = 200 g

m_w = 200 g

Time for ice to melt (t_1) = 1 min = 60 s

Change in temperature of water (Δt) = 20° C

specific latent heat of ice = 336 J g^{-1}

Rate of heat exchange is constant.

Therefore, power required for converting ice to water = power required to increase the temperature of water.

$$P_i = P_w \frac{E_i}{t_1} = \frac{E_w}{t_2} \frac{m_i \times L}{t_1} = \frac{m_w \times c_w \times \Delta t}{t_2} \frac{200 \times 336}{60} = \frac{200 \times 4.2 \times 20}{t_2} \Rightarrow t_2 = \frac{5040}{336} \Rightarrow t_2 = 15s$$

Hence, **time taken = 15 s**

Question 16

During exercise, the body loses heat through evaporation of sweat. If a person loses 1 kg of sweat during exercise, how much energy does the body lose through evaporation? How does the cooling effect of evaporation compare to heat loss due to specific heat capacity? (Latent heat of vaporization = 2268 × 10^3 J kg^{-1}, Specific heat capacity of water = 4.2 × 10^3 J kg^{-1} K^{-1})

Answer

Given,

Mass of sweat lost (m) = 1 kg

Latent heat of vaporization (L) = 2268 × 10^3 J kg^{-1}

Specific heat capacity of water (c) = 4.2 × 10^3 J kg^{-1} K^{-1}

Now,

Energy lost by body through evaporation (Q) = mL = $1 \times 2268 \times 10^3 = 2268 \times 10^3\ J$

And,

To raise 1 kg of water by 1 °C, energy required (q) = mcΔt

On putting values,

$$q = 1 \times 4.2 \times 10^3 \times 1 = 4.2 \times 10^3\ J$$

So, evaporation of 1 kg of sweat causes heat loss equivalent to increasing the temperature of 1 kg of water by :

Equivalent temperature rise = $\frac{Q}{q} = \frac{2268\times10^3}{4.2\times10^3} = 540\ ^oC$

The cooling effect of evaporation of 1 kg of sweat is equivalent to cooling 1 kg of water by 540°C. This shows that evaporation causes a much greater cooling effect compared to simple heating or cooling based on specific heat capacity.